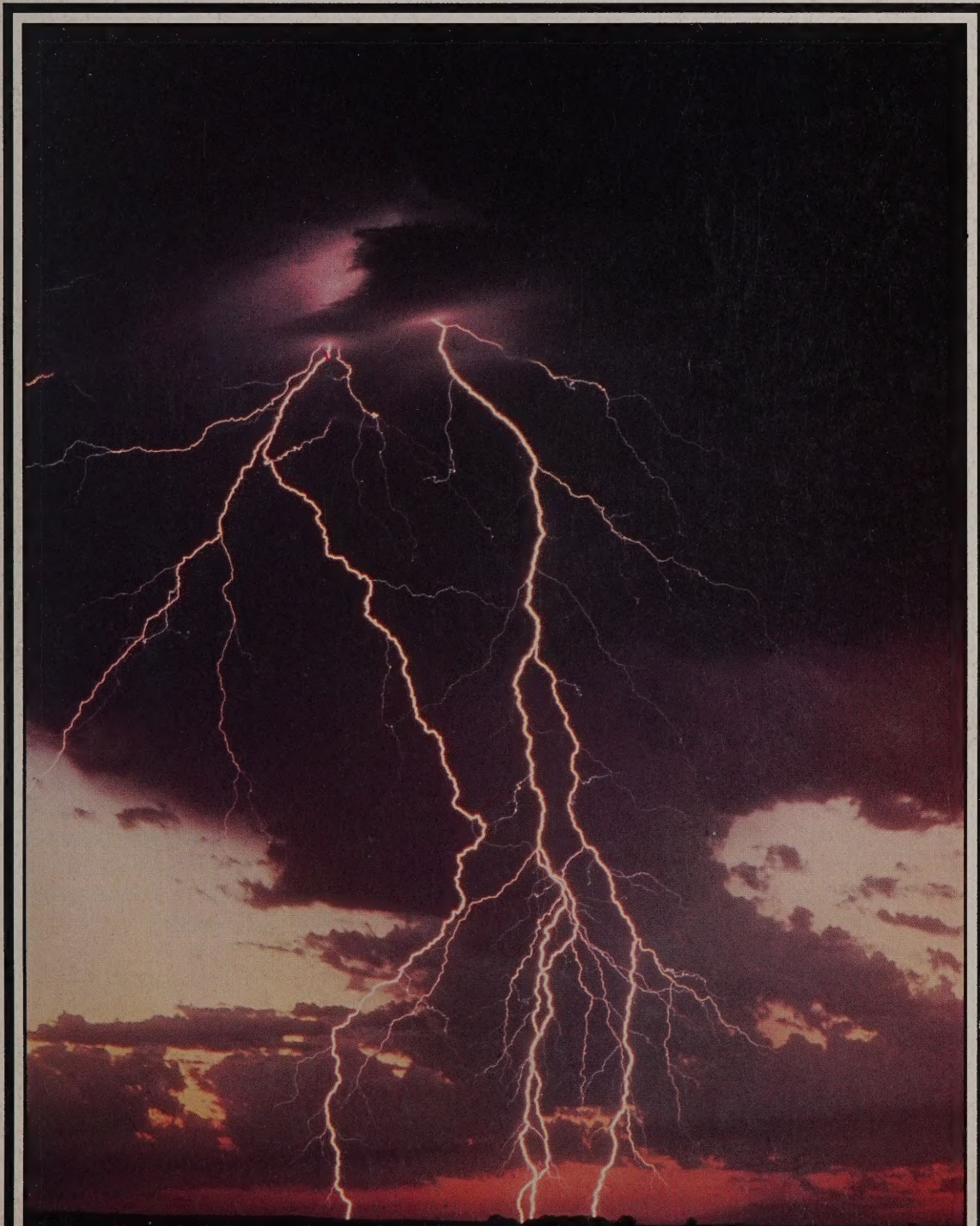


SEPTEMBER/OCTOBER 1990

THE AMATEUR ELECTRONIC COMMUNICATIONS MAGAZINE

BEAM



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EDITOR'S NOTES

Wow! What A Response!

To nearly 20,000 of you, welcome to your first issue of BEAM, a new concept in amateur radio magazines -- a "freebie."

And to the nearly 4,000 of you who returned the qualification form from our premiere July/August issue, welcome back. It's been gratifying to hear from you -- to be so inundated with forms that our data-entry people had to scramble just to enter the names and addresses so you'd get this copy of BEAM. We're still catching up with the demographical information you've given us.

It's also gratifying to receive so many good wishes for success (see just a few of your comments in our *QSL's* on page 4) and to have so many authors respond with offers to write articles (and several enclosed already-written ones, some of which are in this issue).

Several potential advertisers have requested rate kits, and many have been interested in the demographics we're compiling. We are especially pleased that Kenwood has been so supportive of our venture, and we appreciate those who have taken small and classified ads ("little drops of water, little grains of sand...."). We're sure more advertisers will come on board after they decide what their future advertising budgets will include. At least we're hoping that BEAM will be on their minds for the November/December issue and beyond.

You who have sent in qualification forms can help. If you con-



Managing editor Josie, K3SJS, has published more than 200 magazine articles and teaches advertising copywriting at Penn State.



Technical editor Tom, W3IA, has a Ph.D. in physics and is a registered professional engineer who has been an electronics consultant since 1979.

tact any of our advertisers or the companies who have sent us information for *Product News*, be sure to tell them you saw it in BEAM. Remember -- we need advertiser support in order to keep the distribution to you free. Several ham radio equipment manufacturers have told us that they track every inquiry to see where their customers find out about their products. We'd like to hear you say,

"BEAM!" loud and clear.

For those of you getting BEAM for the first time, we hope you like it and will want to continue receiving it every other month. To do that, be sure to return the qualification form for a free subscription bound into the centerspread. We cannot put you on our mailing list for future issues unless you do. Be sure to sign and date your form -- the audit bureau that will be verifying our circulation for advertisers especially needs those two pieces of information.

The extra form is for you to pass along to a friend. Photocopies are also acceptable, in case you want to keep your magazine intact or you want to have lots of forms for a club meeting or hamfest. Libraries and organizations are not eligible for a free subscription to BEAM, but may subscribe at the published rates.

Also remember to keep your address up to date with us so BEAM can follow you wherever you go. And take time to answer all the questions on the form, including the last one. Tell us what kind of articles you'd like to read in BEAM. We want this to be *your* ham magazine.

Until next issue, yours for the fun of ham radio,

73 and 88

QBE?



BEAM

Vol. 1 No. 2

COVER: Iowa photographer Roy Hough captured this spectacular lightning bolt during a Kansas sunset in 1980. To order an 11 x 17 color poster reproduction of this copyrighted time-exposure, see page 29.

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Being an OT, I like the nostalgia. Some of the youngsters *might* learn something. Note -- July/August issue page 30 column 1, 4th line from bottom -- you goofed. One ampere is *not* 6.3×10^8 electrons per second. Look up the exponent again.

Dr. J. Forrest Bigelow, W5VZ
Conroe, TX

[It was a typo. The proper value is 6.3×10^{18} . We only missed by a 1.]

Received the first issue of BEAM. How refreshing! It is the most interesting thing I have seen in a long time. Selfishly, I sure hope it is a success. If I can be of any help, it would be a privilege.

Bob Schaeffer, KJØG
Montrose, CO

Congratulations on an interesting publication. I am sure I will enjoy upcoming issues and thanks for your subscription offer. I found the article on nostalgia [*Reminiscences of an OM*] particularly interesting, since I date back to the "crystal set" era and sprouted my electronic roots with such things as receiver inductors wound on empty oatmeal boxes and super regen receivers using a new-fangled type 30 vacuum tube. Keep up the good work and much success to you and the fledgling magazine. I look forward to the next issue. Best 73 from the Wild West,

Carry Townsend, W3BX
Bartlesville, OK

Thanks for a magazine anyone can understand!

Mark A. Schultz, KE9C
Watertown, WI

Ask Dave Harris, W3ZX [*Reminiscences*] what an 11-inch tube Philco broadcast receiver is.

George J. Cook, W2RBK
Syracuse, NY

[Sorry. Our TV-generation typist added the inch and we missed it.]

Congratulations -- continue much of the same. I have the Millen 6L6-807 [*The Venerable 807*], first store-bought rig, right after war.

Philip V. D'Agostino, W1KSC
Wallingford, CT

Easy to understand. Your *Back to Basics* is super. It has motivated me to study again for a General. Also, license and study info would be a help to upgrading. Keep up the good work.

Betty L. Pierce, WDØDLO
Empire, CO

Nice magazine, good luck!

Stephen R. Muchow, K9AHS
Elgin, IL

First issue was fine. Some technical but not overly so. Not interested that much in contesting or DX -- just having "fun" with ham radio without coming down with a nervous breakdown.

Thomas Nemeth, W2GS
Old Bridge, NJ

Good luck on this new magazine venture. I like and appreciate the first issue, and look forward to future ones. If it proves possible to produce good quality editorial copy without charging a subscription, you will have done something especially valuable, and everything *can* be a source of product educa-

tion if imaginatively used.

Dr. David W. Goodman, KF4N
Rocky Mount, NC

I am very impressed by reading your July/August premiere copy of BEAM, thanks to my good friend Richard L. Congdon, W5FIX, who passed his copy with the extra Qualification Form For Free Subscription on to me. I have been a ham with the same call almost 60 years now. Work cw about 99.44 percent of time and enjoy every minute of it. Gud luck & 73,

Bill Milam, W5AAC
Sulphur Springs, TX

Really great publication. A little something for everyone!

Curt Chezem, WN7K
Eugene, OR

Good luck on your new endeavor!
Doug Maddox, W3HDP
Columbia, MO

I read all of the articles and enjoyed them, especially *Old Timers Soap Box*. Made me think of my late OM, W4DFE.

Lillian O. Bankston, K4DSO
Birmingham, AL

Really enjoyed the 807 history!

Robert Labenski, W1GEH
West Hartford, CT

I am looking for an RCA tube manual which describes the specification of each tube. I can't find any. Could you help me?

Charles M. Baumann KA9VDP
Round Lake Park, IL

QRU?

USA Tops in Radiosport

by Jo Chesworth, K3SJS

Americans took gold, silver, and bronze honors over hams from 14 other countries in the first World Radiosport Team Championship at July's Goodwill Games in Seattle.

Sanctioned by the ARRL and the USSR's Radio Sport Federation, the ten-hour event was sponsored by ICOM America, which provided the same gear for every team. Radiosportmen at 22 stations around Puget Sound raced to make the most contacts on cw and ssb and to talk to the most foreign countries. More than 3,500 amateur radio operators in 150 countries participated, with gold medalists John Dorr, K1AR, and Doug Grant, K1DG, contacting more than 1,400 of them.

WRTC Chairman Danny Eskenazi, K7SS, said, "This marked the first time champions from around the world could compete against each other with similar antennas, radio equipment, and locations. Normally the vagaries of location and gear make big differences in scores. The whole event was bigger and better than we thought it would be."

The Dorr-Grant team scored 263.35 points out of a possible 300. Second, at 255.39, were K7JA and W9RE. Third (254.30): KQ2M and KRØY. Fourth (247.44): the Canadian team of VE7SV and VE7CC. Fifth (247.11): Germany, DL5XX and DJ6QT. Sixth (244.86): Bulgaria, LZ1MS and LZ2PO.

Other teams came from: Brazil,



Boris Stepanoff of the USSR congratulates the winners (from left): Bronze -- Jeff Steinman, KRØY, and Bob Shohet, KQ2M; Gold -- John Dorr, K1AR, and Doug Grant, K1DG; and Silver -- Mike Wetzel, W9RE, and Chip Margelli, K7JA.



Germany's Walter Skudlarek, DL6QT.



Italy's Ivan Fasoli, IK2DVG, and Paolo Cortese, I2UIY. Paolo and Canada's VE7CC won awards for voice and Morse-code accuracy.

Czechoslovakia, England, Finland, France, Hungary, Japan, Spain, USSR, and Yugoslavia.

Five-time Yugoslavian champion Tine Brajnik told a *Seattle Times* reporter, "Nobody is under any pressure politically or religiously when sitting behind the radio. There's always a friend on the other side."

Although the Soviet Union bestows on amateur radio masters the same honors given champion weightlifters and gymnasts, radiosport is not recognized by the Olympics. "But," Eskenazi says, "a federation has now been formed to pursue international sanctioning of this type contest, and they plan to talk to the Olympic committee."

With luck, amateur radio, like chess, will be part of the next Olympic Games. FB!

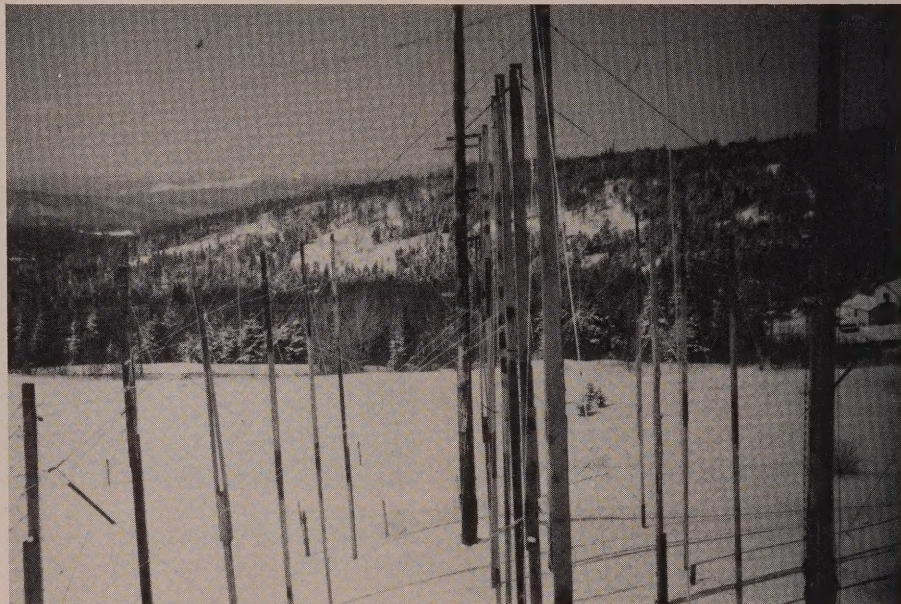
Antenna Farming, New England Style

by Charley Morgan K1GZL

Up here in the North Country, about four miles from the Canadian border in the wilds of New Hampshire, an ordinary self-supporting rotatable beam on a tower can be severely damaged or destroyed by a good shot of freezing rain during the winter months. The annual snowfall is 150 inches or more, and we are under snow for an average of five months.

Generally, snow is not damaging to antennas but ice is. To avoid this problem I decided to try wire beam antennas on the hf bands, the advantage being that you can drop key ropes which support the beams before the ice builds up during a storm, then haul them back up after it is over. The disadvantage is that the fixed-wire antennas are not rotatable and you are stuck with one main lobe direction, unless you install other beams pointing in other directions and switch from one to the other.

Much of my operating involves schedules with old friends and participation in nets. For this work the fixed beams are ideal since they give me a good signal into a pre-selected area even when band conditions are poor. I have run on-the-air checks of my antennas and the results have been most satisfactory. On 20 meters I ran some low power checks into New Zealand, and, using one watt, I was able to produce an S-8 signal.



Part of K1GZL's antenna farm, which incorporates more than 6,000 feet of rope.

Another evening I was down to ten milliwatts and was partially readable to "Hip," ZL2ANB, who was having some line noise from a leaking transformer during a heavy rainstorm. That night he was hitting only forty-five to fifty over S-9 when on very good nights he pegs the meter on my KWM2. This means he could have received my signal on his three-element delta loop even if I had been using one-thousandth of a watt. Normally I use a KWM2 winged label transceiver and an SB220 linear amplifier.

Based on this and other tests, I found that the beams gave me a worthwhile increase in station performance. As a guide to others who might want to try some wire

beams, I am including information on the antennas at my QTH. These dimensions can be used as starting points for developing optimum antennas for your own requirements or can be copied exactly by those who want to save the trouble of cutting and trying.

Choosing Antenna Height

The elevation at my QTH is 2,020 feet above sea level, which has very little to do with the skip in the ionosphere. However, slope of the ground and its conductivity are factors that should be considered. In many installations it will be impractical to install a wire beam high enough for ground to be a negligible factor in antenna

performance (say several wavelengths high). The appropriate height for the wire beam at a particular QTH is best found by trial and error, since every location is different. By leaving one dipole at a fixed location for reference and using another one at varying heights, you can find out what height is the best at your QTH. Adjust the height of the variable dipole to maximize its signal with respect to the fixed reference dipole. Once this height is found, build the antennas at that height. The signal variation with height is really exciting to watch.

In putting up the 15 meter antenna I ran experiments with a fixed dipole at fifty feet; the variable antenna wound up at twenty feet. The lower dipole outdid the higher one by an average of five dB.

Having determined the antenna height, the next step is to install the wire beam. I have three beam antennas at this QTH: a 40 meter four element V beam, a 20 meter five-element quad, and a 15 meter eight-element quad.

40 Meter V Beam

The 40 meter beam is in the inverted V configuration. The beam is over ground which slopes gently downward in the main lobe direction. The center of the driver element is fifty feet from the ground while the center of the second director is about sixty-two feet up. The elements slope downward at about thirty-five degrees to their tips. Element lengths and spacings for the 40 meter beam are shown in Table 1.

All the elements are of solid No. 14 copper insulated wire. The feedlines to all these antennas are 52 ohm foam coax using multiples of half waves in the cable. These lengths are calculated taking the velocity factor into consideration. All of these antennas use parasitic

| Element Lengths | |
|-----------------------------------|-------------------|
| Reflector: | 67 feet 1½ inches |
| Driven Element: | 64 feet 10 inches |
| First Director: | 62 feet 5 inches |
| Second Director: | 61 feet |
| Spacing | |
| Reflector to Driven Element: | 26 feet |
| Driven Element to First Director: | 21 feet 6 inches |
| First to Second Director: | 22 feet |

Table 1 : Forty Meter Four Element Wire Beam

| Element Lengths | |
|-----------------------------------|-------------------|
| Reflector: | 70 feet |
| Driven Element: | 67 feet 3 inches |
| First Director: | 64 feet 8½ inches |
| Second Director: | 62 feet 2½ inches |
| Third Director: | 62 feet 5 inches |
| Spacing | |
| Reflector to Driven Element: | 13 feet 4 inches |
| Driven Element to First Director: | 12 feet 6 inches |
| First to Second Director: | 13 feet 1 inch |
| Second to Third Director: | 14 feet |

Table 2 : Twenty Meter Five Element Wire Quad

| Element Lengths | |
|-----------------------------------|-------------------|
| Reflector: | 47 feet 4½ inches |
| Driven Element: | 45 feet 10 inches |
| First Director: | 44 feet 5 inches |
| Second Director: | 44 feet ½ inch |
| Third Director: | 43 feet |
| Fourth Director: | 43 feet 6 inches |
| Fifth Director: | 44 feet 1 inch |
| Sixth Director: | 43 feet 6 inches |
| Spacing | |
| Reflector to Driven Element: | 7 feet 3 inches |
| Driven Element to First Director: | 4 feet 1 inch |
| First to Second Director: | 4 feet 10½ inches |
| Second to Third Director: | 10 feet 8 inches |
| Third to Fourth Director: | 12 feet 5 inches |
| Fourth to Fifth Director: | 14 feet 6 inches |
| Fifth to Sixth Director: | 15 feet 3 inches |

Table 3 : Fifteen Meter Eight Element Wire Quad

elements -- there are no connections whatsoever between the elements. On 20 and 40 meters I use rope to hold the elements to the right spacing. On 15 meters I use many poles, which eliminates the need for rope to hold the various

elements in the proper places.

On both 20 and 40 meters the lengths in the tables favor the phone band, but the SWR is very passable down through the cw frequencies. The 15 meter quad initially covered the low end of the

band with a low SWR. Installing the very close-spaced first director increased the SWR at the low end, but it is still very good with the director in place.

15 and 20 Meter Quads

The 15 and 20 meter quads are both in a diamond configuration. The 20 meter antenna is fed at the bottom and the 15 at the top. This makes them horizontally polarized. When a quad is fed on the side, it is vertically polarized. I tried feeding the 15 meter wire quad on the side, and the forward gain dropped at least twenty dB. I could measure this change using a 15 meter dipole as a reference. The dipole started performing as well as the 15 meter quad both on transmitting and receiving.

The 20 meter antenna is a five-element quad whose dimensions are shown in Table 2. The base of the 20 meter driven element is about twenty-two feet off the ground. As you go out toward the front of the quad, the ground slopes down gently, putting the base of the third director ten feet higher off the ground than the driven element. Out in front of the quad, the ground drops off more gradually until the center line of the quad is approximately fifty feet off the ground 150 feet in front of the beam. The reflector consists of two pieces of Nos. 12 and 14 insulated solid copper wire wrapped together. The rest of the elements consist of No. 14 insulated solid copper wire.

Notice that starting with the third director the element length becomes slightly longer. This increase in length would continue in the element of the fourth director, if I had one, but it starts to shorten up again with the fifth director. In the 15 meter eight-element wire quad the lengthening effect starts with the fourth director because I have added a very close-spaced



Charley K1GZL at his rig (photo by Andy Hicks)

first director between the driven element and the original first director, which is now the second director. I thought a close-spaced parasitic element might help, and found that a close-spaced first director inserted just in front of the driven element gave a slight bit more gain -- so I kept it.

Table 3 shows the dimensions of the 15 meter quad. In this antenna, the bottom of the driven element is only ten feet off the ground. The base of the sixth director is close to twenty-three feet off the ground. Out in front of the beam the ground drops off so that the center line of the quad is more than fifty feet up, a little over a wave length from the driver element. The front-to-back spacing of the 15 meter quad is $69\frac{1}{2}$ feet, or a little over one-and-a-half wavelengths. All wire is No. 14 insulated solid copper.

When viewing the quad beams from the back looking through the elements toward the front, it is best to have all of the elements lined up properly. I have had to add one or two short lengths of coaxial cable taped together and put on the bottom part of the diamond-shaped elements to keep the elements lined up correctly. You have to experiment with how much weight to attach, although this alignment is not extremely critical.

Someday I hope to put up one more wire quad on 20 meters. This

antenna would be directed toward Alaska and Japan at right angles to and somewhat interlaced with the front of the present five-element wire quad.

Before I put up the 15 meter wire quad I had an eight-element horizontal wire yagi. The quad has more gain over the fixed 15 meter reference dipole than the horizontal yagi did. With the yagi I tried changing over to bare wire and everything worked out fine until one October afternoon when wet snow accumulated on the wire beam. The SWR shot upward, the gain went down, and the signal went down the tubes -- even during rainy weather there was a large loss factor. From now on I'm staying with insulated wire, believe me.

Charlie has a back yard that, in a friend's words, "looks like a giant spider web." He enjoys building and rebuilding his antenna farm, and, by careful relative measurements coupled with trial-and-error experimentation, he has managed to grow a set of antennas which blow the socks off the competition. His address is: R.R. 1, Box 410-A, Pittsburg, NH 03592.

Classifieds

BEAM's classified rate is 85 cents per word, paid in advance. No illustrations. Mail to: P.O. Box 650, Boalsburg, PA 16827

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Lightning and the Radio Amateur

by Tom Chesworth, W3IA

Lightning is extremely dangerous and unpredictable in its behavior. Because of towers and antennas, radio amateur equipment enhances the probability that lightning will strike. Since you, your property, and your amateur radio equipment are at risk, it is the worst sort of foolishness not to take simple precautions. No lightning protection is perfect, but some simple, inexpensive procedures can put the odds of not being struck in your favor.

The Nature of Lightning

In most of the continental United States, from the Rockies to the Atlantic, there are an average of twenty thunderstorms a year between March and September, as shown in Figure 1. There are fewer in New England and on the West Coast, more in Florida, Alabama and Georgia. The most thunderstorms -- more than forty -- occur in the St. Petersburg area, while the fewest occur in Alaska, which has only one or two a season. From October to March there are, on average, only three to five thunderstorms in the Southeast and Midwest and one or two elsewhere in the United States.

The probability of any one place being struck by lightning is small. You are as likely to win the Irish sweepstakes as to be hit by lightning -- unless you are a radio amateur. Hams are more likely to be



Simple, Free, and Effective Lightning Protection

Do not operate when thunderstorms are in the area.

Disconnect the antenna leads when equipment is not in use and when thunderstorms threaten.

Pull the power plug on your equipment when it is not in use and when thunderstorms threaten.

killed by lightning because the old adage that it never strikes twice in the same place is wrong. In fact, lightning is very likely to strike repeatedly at exactly the same place -- the antenna masts on top of the World Trade Center, a lone tree atop a ridge, or a 48-foot tower with a 20 meter beam on top. All are prime candidates for multiple lightning strikes. Whenever the geometry is right for concentrating the earth's electric

field, it is nearly certain that lightning will strike that site during a violent thunderstorm.

The sequence of events during a lightning strike begins when the charge builds up in the thundercloud -- probably near the -10 degrees Celsius isotherm. The generating mechanism may be associated with the formation of ice crystals in the presence of super-

Lightning Photo Courtesy of National Severe Storm Laboratory

cooled water droplets in this region. The electric field in the vicinity increases until the air ionizes at about 3×10^6 V/meter. A pilot leader grows at about 160 km/hr in the general direction of the ground. After it has extended about 30 to 45 meters, a more intense discharge, the step leader, moves appreciable charge into the ionized column which raises the local electric field and allows another pilot leader to advance another 30 to 45 meters. These pilot leaders move toward the earth in the direction in which the air is most easily ionized. The ease of ionizing the air has to do with moisture content, aerosols, air temperature, etc. The chaotic gusts in thunderstorms cause the air to be very inhomogeneous, and the vagaries of the ionization of the air give the path its characteristic zig-zag appearance.

Due to the low resistance of the ionized air the charge density in the ionized column is about the same as the charge density in the cloud. As the step leader approaches the ground, positive charge builds up in the region below its leading edge. Structures such as towers concentrate the field gradient in their vicinity due

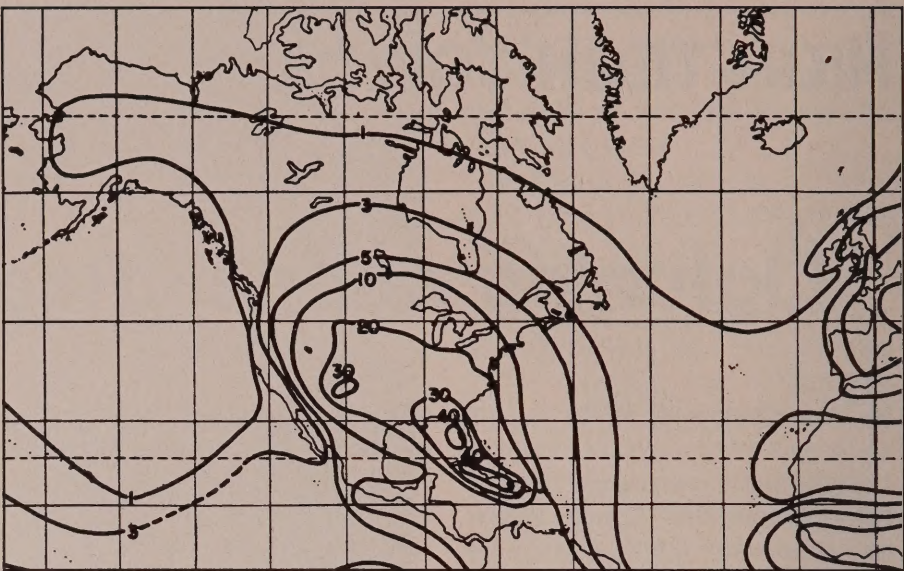


Figure 1: Average Number of Thunderstorms March-October
(map from *Climatology*, Haurwitz & Austin)

to their pointed shapes. The result is that the air is most easily ionized near their tops, and the step leader tends to connect them to the charge region in the cloud via the ionized air column.

Once the connection is made, the positive charge in the earth surges up the ionized column to neutralize the charge region in the cloud. This return stroke is the major lightning stroke and can be of the order of hundreds of thousands of amperes for fifty or so milliseconds.

The currents flowing in the air are by and large not due to free electrons. In the air near the ground a free electron rapidly combines with a wet air molecule to form a negative-hydrated ion. It is the ions moving via the ionized channel at about 160 km/hr which form the current. Air molecules near the surface of the tower give up one or more electrons to the tower. The positive ions created in this way move upward through the column and neutralize the charged air in the cloud.

| Typical Lightning Parameters | | | |
|------------------------------|--------------|---------------|------------|
| | Minimum | Typical | Maximum |
| Current | 1 kA | 10-20 kA | 250 kA |
| Lightning Duration | 0.05 s | 0.2 s | 2 s |
| Return Stroke Duration | 50 ms | 150 ms | 500 ms |
| Time Between return strokes | 3 ms | 40-60 ms | 100 ms |
| Number of return strokes | 1 | 2-4 | 26 |
| Pulse rise times | <0.5 μ s | 1.5-2 μ s | 30 μ s |

Table 1: Data from MIL-HDBK-419

Once the charge region is partially neutralized, the process usually starts over again; charge builds up in the same region. Since the channel still has residual ionization, it is the most likely air to be ionized by essentially continuous dart leaders. When connection is made again about 50 milliseconds later, another return stroke may occur.

Table 1 shows data concerning the numbers and durations of these processes in lightning strokes. Once a stroke is completed, the cloud-charging mechanism can cause another stroke in about 20 seconds. About 65 percent of the lightning strokes are between charge areas in the same thundercloud or are cloud-to-cloud strokes.

The Good News

A well-grounded tower carefully bonded at its joints so that it can carry thousands of amperes will lead the lightning energy away from the ham, from the amateur equipment, and from the house and grounds. In addition, since the lightning is more likely to hit the tower, it is less likely to hit elsewhere in the vicinity. In fact, the tower will protect structures surrounding it up to a distance of three times its height (figure 2).

Better yet, under some conditions the tower even tends to discourage lightning from striking in the vicinity. Before the pilot leader can connect the tower to the charge in a thundercloud, St. Elmo's fire from the tip of the tower may dissipate the charge nearby. The field gradients become much less and the pilot leaders are attracted to a different place.

As an alternative to installing bond straps or brazing joints on your tower, consider a straight run of hard-drawn copper water pipe, bonded to a copper-clad steel ground rod at the base, running

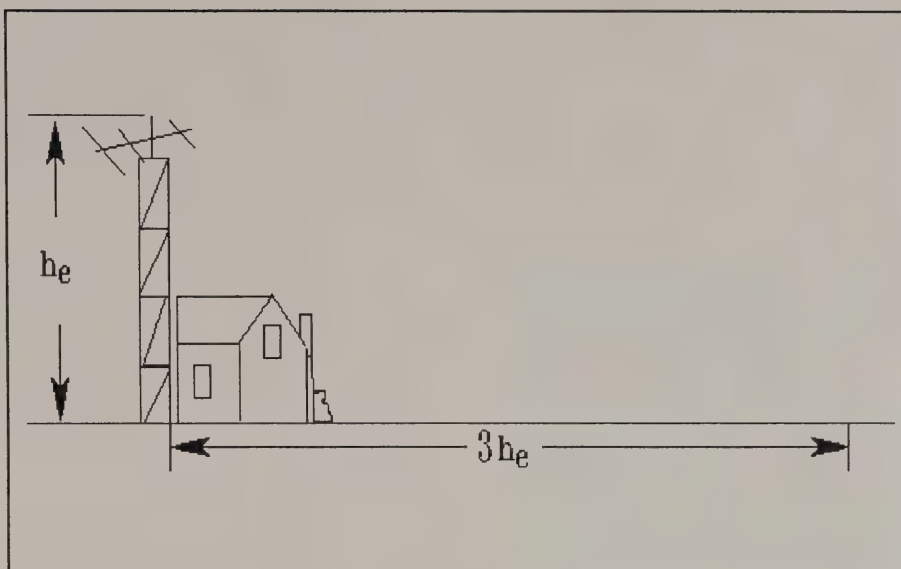


Figure 2: Protected Zone Near Tower

straight up inside the tower to the top. Lightning current is high frequency RF, so the ground conductor should be a straight low-inductance path. Any bend or turn in the ground conductor may have enough inductance to cause the current to jump to an adjacent conductor.

The Bad News . . . And What To Do About It

Due to the random ion paths, the arcing in the ionization column, the pulsing step leader and dart leaders, and even the fast rise-time of the return stroke, lightning has strong spectral components up to about 600 kHz and significant RF energy even into the HF and VHF region. Much of the unpredictable and capricious conduction of lightning currents can be better understood when conductor inductance and the RF nature of the lightning currents are considered.

The threat to human life and destruction of property due to fire can best be countered by inducing the lightning to strike elsewhere and dissipate harmlessly into the earth. This can be done at your shack by using your tower or the

supports for your half-wave dipole as a lightning rod, as previously suggested.

The next important step is not to lead lightning currents from your "lightning rod" to you, your equipment, or into your house. Disconnect your antenna lead-ins when your equipment is not in use and when thunderstorms are in the area. Remember, lightning moves by ionizing air -- be sure to separate the lead-in and the jack or whatever by at least a meter.

To take advantage of your lead-in's inductance, make a coil about 10 cm in diameter out of about 2 meters of lead-in (coax). The same trick will work against common mode lightning transients on the power line. Loop the zip cord and hold the choke in place using garbage bag ties or electrical tape. These chokes are not in themselves reliable protection against lightning transients but they can help, and the price is right.

Commercial lightning arresters come next. They are effective if properly grounded and should be included in a lightning protection system. Most of them work by shunting the lightning current to ground -- that is, producing a short circuit in parallel with the equip-

ment -- while the pulse is present. Typical gas discharge devices activate in several micro-seconds, limit pulses to 500 V or so, and survive very energetic spikes. MOV's activate in less than a microsecond and limit pulses to about 10 volts but cannot tolerate high energy pulses. Various solid state diode-like devices (surgistors, Zener diodes, etc.) act quickly enough and limit voltages to levels where solid state circuitry is protected. In a typical installation all three types of suppressors are used. The lightning arrestor protects the MOV. There is often a resistor or choke in the circuit which, with the MOV, enhances the voltage division to help protect the surgistor. There may be a resistor or inductor used with the surgistor which enhances the voltage division there to protect the circuitry.

About 65 percent of lightning strokes are within a cloud or are cloud-to-cloud. These 100 kA currents changing at hundreds of kHz can and often do induce kilovolt transients into the loops formed by the power lines on the power poles and the neutral-ground return through the earth. For this reason and because a ground stroke in the vicinity often causes a current pulse on the power grid, power-line lightning-induced transients are much more prevalent than antenna-induced stroke transients. If you have a PC computer and do not have a surge arrestor in your power strip, you know what these transients do to modern solid state equipment. The power line transients are by and large only an equipment problem. The best and cheapest solution is to pull the plug. Coiling the power cord can be useful and is also free. Power strips with surge suppressors are relatively inexpensive and work well.

The third way lightning can affect your equipment is via the grounding system. High voltage

transients can be induced in equipment from grounds in two ways:

First, the large currents in local lightning strokes can induce potentials in loops formed by the grounds interconnecting the equipment. For example, a large voltage transient can be induced in the loop formed by the coax outer conductor, the green wire to the power amplifier, and the green wire to the exciter. Once generated, these transients can couple by cross talk into susceptible transistors and integrated circuit chips.

Second, the large lightning currents of thousands of amperes can create voltage transients. The ground resistance is usually 1 to 3 ohms for a well-designed ground grid and may be 20 to 50 ohms for a poorly installed ground rod. These currents in the ground resistances cause large surface voltage drops in the earth adjacent to the lightning rod (antenna tower). If two separate grounds, say the power ground at the power service entrance and the ham RF ground connected to the water pipe are not in the same place, the step distance between the grounds may cause a large step voltage in the ground system which can couple to the susceptible circuitry by cross

talk (see figure 3).

Disconnecting the ham radio ground will help the second problem. **Do not remove the green wire safety grounds from your equipment.** The zip cord itself or the inevitable pigtail of green wire inside your rig where the safety wire is connected can be wrapped several (say eight) turns around a toroidal ferrite core. If you wrap the green wire in your rig around a core, carefully bolt it back onto the chassis. This choke will give some protection from lightning-induced transients and power line noise. Careful design and control of the ground interconnections in your shack to eliminate ground loops will help protect your gear from lightning transients.

Finally, if you are ever in the middle of Field Day or just about to zero in on that elusive OX5 just readable on 15 and you hear QRN which builds up then abruptly stops then builds up again with a twenty or thirty second cycle, immediately pull off your headphones disconnect your antenna, and pull the power plug. Then look outside to see if the sky is black and menacing. On your antenna tower or the nearby trees you may even see St. Elmo's fire.

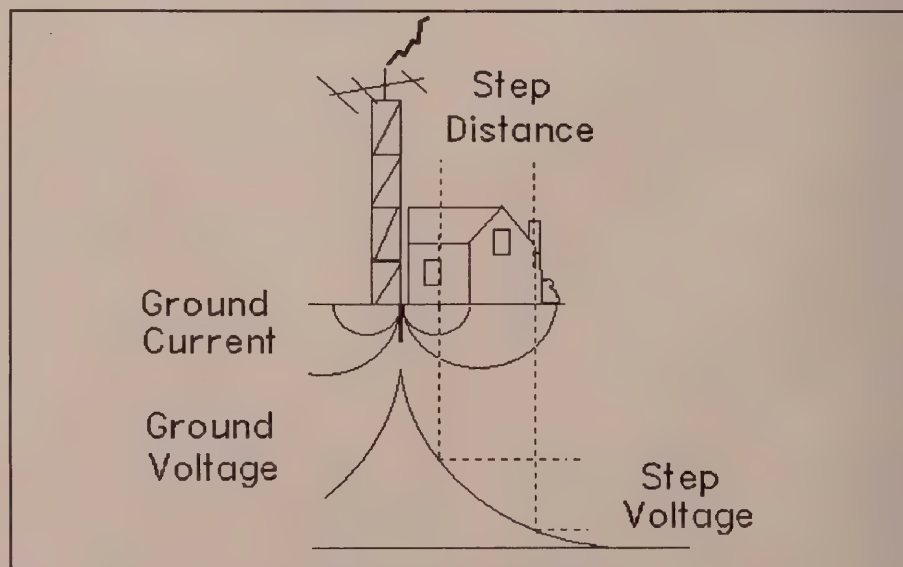


Figure 3: Lightning Induced Step Voltage

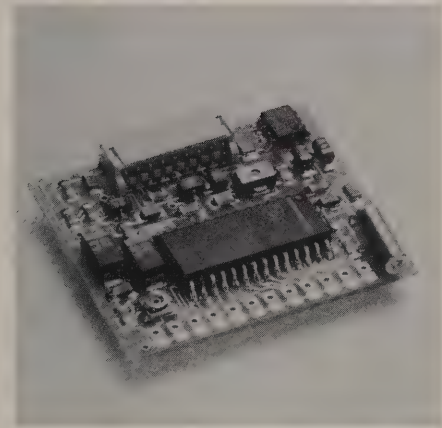
PRODUCT NEWS

Panel Meter Catalog

A new catalog from Shurite offers over 260 standard range ± 5 percent accuracy panel meters. A selection guide lists stock numbers, ranges and resistances in major product categories, and there are mechanical drawings for all main products.

Specially featured are new double-duty meters designed to mount either behind-the-panel or in-front-of-the-panel. A line of test instruments is also detailed.

Contact: Shurite Meters, Box 185, North Branford, CT 06471. Phone (203) 481-5721, FAX (203) 481-8937.



New Digital Encoder-Decoder

A new microminiature Digital Coded Squelch encoder-decoder is now available from Communications Specialists, Inc.

Compatible with other DCS systems, such as "Digital Private Line", "Digital Channel Guard", and "Digital Call Guard," the new board is constructed using surface-mount technology and measures

1.36" x 1.18" x .25", which permits installation in all mobile and most portable radios. All industry standard digital codes are field programmable with PCB jumpers. A crystal-controlled CMOS microprocessor permits operation on a very low 6 to 20 vdc at 8 ma.

Price of the DCS-23 is \$59.95 with a one-year warranty.

For more information and a complete product list contact: Communications Specialists, Inc., 426 W. Taft Ave., Orange, CA 92665-4296. Phone (800) 854-0547 or FAX: (714) 974-3420.

MFJ MultiCom Software

MFJ Enterprises, Inc. announces the release of its new MFJ-1289 MultiCom™ IBM compatible software for the MFJ-1278. Price is \$59.95.

This "load and use" software requires no setup to transmit and receive multi-gray level Weather Fax maps, AP news photos, and (pictured above) SSTV pictures. You can also transmit and receive full-color packet pictures.

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an MFJ-1278 with multi-gray level modem or other MFJ TNC and an IBM XT/AT or compatible computer with 512K RAM. Its graphics work with CGA, EGA and VGA, picture quality depending on system used. This copy-protected software comes on three 5-1/4" disks (3-1/2" disks are available), and can be installed on your hard disk drive.

For more information or to order, contact any MFJ dealer or MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, MS 39762, phone (800) 647-1880 or FAX (601) 323-6551.

Super-Compact HTs

Kenwood announces the smallest in its HT Series -- the all-new TH-27A (pictured on next page) for 2 meters and the TH-47A for 70 cm. Super compact and beautifully designed, these pocket-sized twins give you full-size performance. Features include: large capacity NiCd battery pack for extended transmit time; extended receive coverage -- TH-27A: 118-165 MHz; TH-47A: 438-449.995 MHz; transmit on amateur bands only (TH-27A modifiable for MARS/CAP); multi-function scanning; frequency step-selectable for quick QSY; live-watt output; dual

tone squelch system; tone alert that beeps when squelch is opened, and DTMF memory, allowing repeater control codes to be stored.



Suggested retail prices are TH-27A: \$419.95, TH-47A: \$429.95. See authorized Kenwood amateur radio dealers for more details.

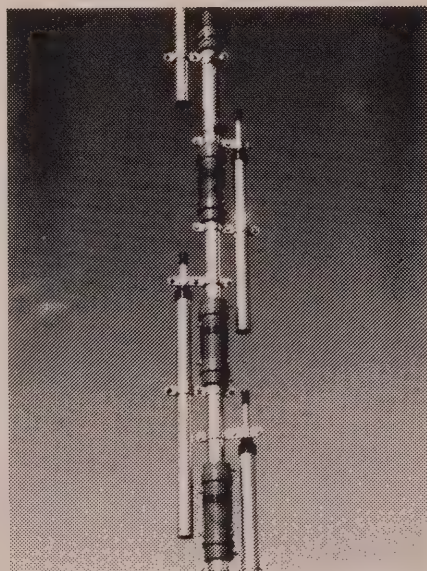
New, Super-Versatile HF Vertical Antenna

Telex Hy-Gain has introduced the DX88, the first tunable omnidirectional vertical antenna designed for Amateur, MARS, and SWL uses.

The DX88 can be tuned to eight

amateur bands between 10 and 80 meters, to any eight of the twelve international SWL bands between 11 and 90 meters, or to any of the Air Force, Army or Navy MARS frequencies adjacent to the amateur bands. It can also be set to any combination of Amateur, SWL, Utility, or MARS bands.

Suitable for limited space, it is 25 feet (7.5 m) high, with ground radials of 14 feet (4.3 m). It is constructed of thick-wall aluminum tubing, stainless steel hardware, and withstands 80 mph (130 km per hour) winds, unguyed. The antenna also can handle full legal amateur radio power.



Suggested list price is \$299.00, with radial kits and a 160 meter loading coil optional. The first

production run has already been delivered to dealers, or contact: Telex Communications, Inc., 9600 S. Aldrich Ave., Minneapolis, MN 55420, phone (612) 884-4051 or FAX (612) 884-0043.

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☐ General

2) ☐ Planning to obtain an amateur license

3) ☐ Short Wave Listener

4) ☐ Electronics Hobbyist

B. How many other people in your household are interested in this same hobby? _____

C. Do you work in the electronics industry?

☐ Yes ☐ No

D. What is your occupation? _____

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Type _____

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G. What type of equipment do you own? (Check all that apply, then circle the one used most often.)

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|--|-------|-------|
| <input type="checkbox"/> Receiver | _____ | _____ |
| <input type="checkbox"/> Transmitter | _____ | _____ |
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| <input type="checkbox"/> VHF/UHF transceiver | _____ | _____ |
| <input type="checkbox"/> HF transceiver | _____ | _____ |
| <input type="checkbox"/> Beam antenna | _____ | _____ |
| <input type="checkbox"/> RF power amplifier | _____ | _____ |
| <input type="checkbox"/> Computer | _____ | _____ |
| <input type="checkbox"/> Mobile rig | _____ | _____ |
| <input type="checkbox"/> Other | _____ | _____ |
| <input type="checkbox"/> None at present | _____ | _____ |

H. Operating modes used: (Check all that apply, then circle the mode used most often).

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☐ RTTY ☐ FM ☐ Satellite ☐ AM

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Year first licensed _____ Call Sign _____

License Class: ☐ Extra ☐ Technician
☐ Advanced ☐ Novice
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☐ Yes ☐ No

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Type _____

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G. What type of equipment do you own? (Check all that apply, then circle the one used most often.)

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| <input type="checkbox"/> HF transceiver | _____ | _____ |
| <input type="checkbox"/> Beam antenna | _____ | _____ |
| <input type="checkbox"/> RF power amplifier | _____ | _____ |
| <input type="checkbox"/> Computer | _____ | _____ |
| <input type="checkbox"/> Mobile rig | _____ | _____ |
| <input type="checkbox"/> Other | _____ | _____ |
| <input type="checkbox"/> None at present | _____ | _____ |

H. Operating modes used: (Check all that apply, then circle the mode used most often).

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I. Bands Used: (Check all that apply, then circle the band used most often).

☐ 1-9 MHz ☐ 30-300 MHz
☐ 9-30 MHz ☐ 300 MHz and up

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Microprocessor vs Amateur Radio

by Daryl Gerke, KØFBF

In the July/August *BEAM* we looked at interference to computers and microprocessors caused by radio transmitters. This issue we'll look at the other side of the problem -- RFI generated by computers, causing interference to nearby receivers.

Almost anyone with a computer in the ham shack has experienced computer-RFI, which shows up as "whistles, chirps, and birdies" on HF and even VHF receivers. And although FCC regulations limit RF emissions from computers, these rules were designed to protect nearby television receivers, and not much more sensitive ham receivers.

This article discusses the problem, and provides some guidelines for diagnosing and fixing it in your ham station.

The Source-Path-Victim Approach

When dealing with any interference problem, it is helpful to break the problem into three components -- the source, the victim, and the coupling path. In this case, the source is a computer (clock circuits being the worst offenders), the victim is a sensitive radio receiver, and the coupling paths are via direct radiation and/or power and signal cables.

The computer-RFI situation is shown in Figure 1. Note that multiple paths exist, and that any

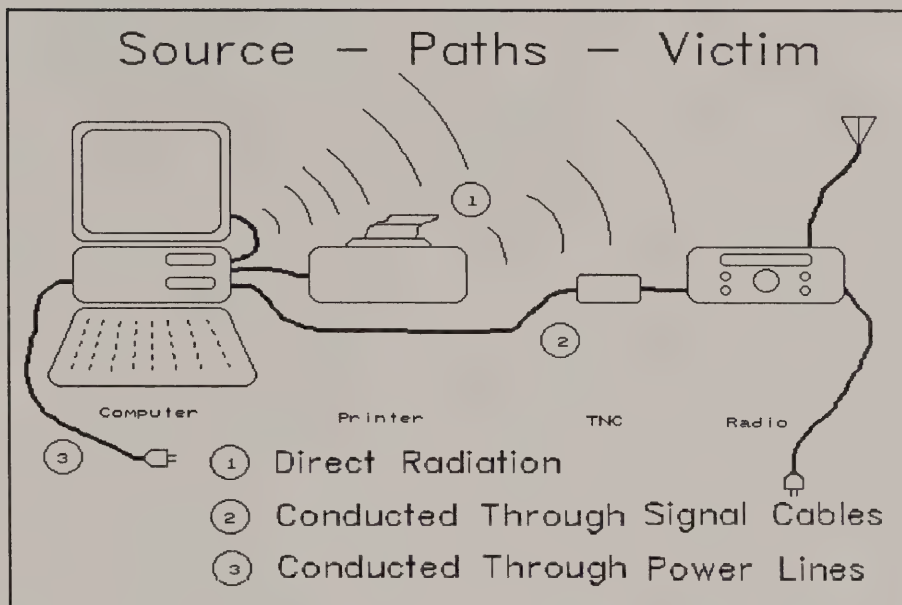


Figure 1

or all may be contributing to the problem. Unintended energy can be coupled by electromagnetic radiation, or directly via the power and signal wiring. This is why filtering may work today where shielding worked last week, and tomorrow you might need both.

The Computer as a Source

The "clocks" or other highly repetitive signals are the principal source of emissions from a computer system. The harmonics of these signals result in discrete narrowband signals that often extend well into the VHF and UHF range. These unintended harmonics can be easily radiated by systems cabling and wiring, which can act as fairly efficient antennas at high HF and VHF frequencies.

This energy can also couple easily onto receiver power or signal wiring.

A useful tool to predict and understand these emissions is Fourier analysis, which says that any non-sinusoidal waveform is composed of a fundamental frequency plus harmonics. Square or trapezoidal waves, such as computer clocks, are very rich sources of these harmonics. Figure 2 shows the Fourier spectrum of a clock signal. When the frequency is plotted in a log-log format (Bode plot), the slopes and break points become very apparent. The first "break point" is related to clock speed, as clock speeds increase, so do the levels at any given frequency. For example, if the clock is increased from 5 to 15 MHz, the harmonic amplitude at any given

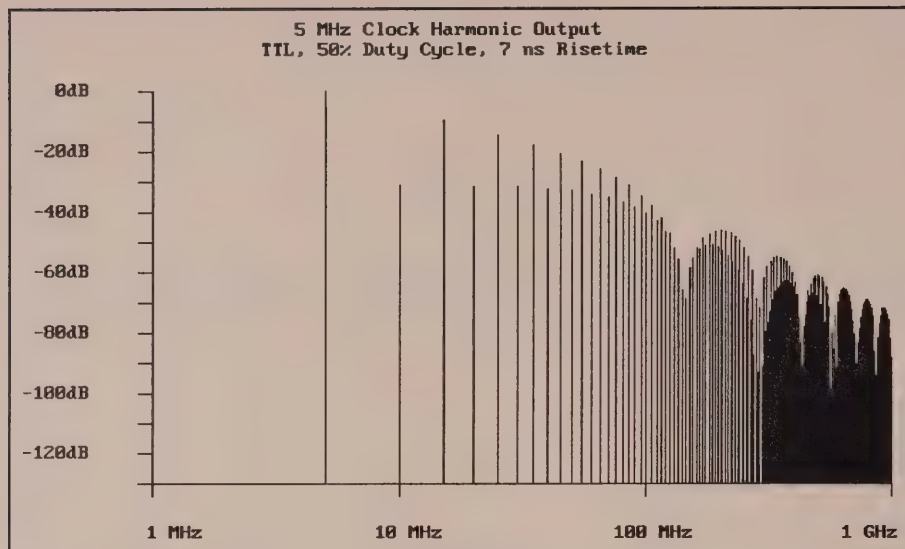


Figure 2

frequency will triple. Simply stated, the higher the clock, the hotter the system.

The second "break point" is related to the logic edge rates, where the harmonics start to diminish more rapidly. This is sometimes referred to as the "logic bandwidth", and is much higher than the clock frequency. With today's typical 1-3 nanosecond edge rates, the "logic bandwidth" is in the 100-300 MHz range. No wonder today's computers are "hot" even into the VHF and UHF ranges.

Cables as Antennas

If the computer is a transmitter, then the interconnecting cables are its antennas. All hams are aware that at 1/4 wavelength or more, any wire or cable can be an effective radiator. But even shorter wires can radiate, so in the interference world any wire or cable over 1/20 wavelength is considered an antenna. On 80 meters, this is about 13 feet, but at 20 meters this decreases to 3 feet, and on 10 meters this is about 18 inches.

These antenna effects explain why the "computer birdies" are often a bigger problem on the higher bands, where cables to printers, modems, and keyboards

can become efficient antennas if unwanted clock harmonics are coupled to them.

Receivers as Victims

Communications receivers are particularly vulnerable victims to interference that occurs at the frequencies to which they are tuned. Fifty microvolts of unwanted energy at the antenna results in an S-9 interference signal. This energy can enter directly through the antenna, or indirectly through power or other low frequency wiring, as shown in Figure 1.

Obviously, energy entering directly through the antenna must be suppressed at the source, or

blocked by shielding before reaching the receiver antenna, since the receiver can't discriminate between desired and undesired signals at the same frequency. The indirect energy, however, can be blocked at either the computer or the receiver by filters on the power or signal lines.

FCC Requirements

With the proliferation of computers in the late 1970s, computer-RFI problems caused the FCC to establish radiated and conducted emission limits for computer equipment. These limits were aimed at protecting television and commercial broadcasting receivers from nearby computer-RFI.

Two classes of limits were developed, commercial (Class A) and residential (Class B). The Class B limits are about 10 dB, or three times more stringent. Radiated emissions are measured from 30 MHz to 1 GHz, and conducted emissions on power lines are measured from 450 KHz to 30 MHz. These levels are shown in Table 1.

Although the FCC limits do a good job of protecting television and AM/FM broadcast receivers against computer-RFI, they provide only moderate to weak protection for communications receivers. First, the FCC limits do not

| R A D I A T E D | FREQ.-MHz | CLASS A* (30 Meters) | CLASS B (3 Meters) |
|--------------------------------------|------------|-------------------------|-----------------------|
| | 30 - 88 | 30 uv/m | 100 uv/m |
| | 88 - 216 | 50 uv/m | 150 uv/m |
| | 216 - 1000 | 70 uv/m | 200 uv/m |
| C O N D | 0.45 - 1.6 | 1000 uv | 250 uv |
| | 1.6 - 30 | 3000 uv | 250 uv |

* For equivalent Class A values at 3 meters, multiply by 10.

Table 1 : FCC Limits

even test for radiated emissions below 30 MHz, and second, communications receivers are typically 100 to 1000 times more sensitive than television receivers. The FCC limits are certainly better than no limits at all, but they are no guarantee of computer-RFI free operation in the ham shack.

How to Fix Computer RFI-Problems

Now that we've discussed computer-RFI problems, what can we do to prevent or fix them in the ham shack? Here are some suggestions, summarized in Figure 4:

Buy an FCC Class B Computer

Any computer sold for home use must meet the more stringent Class B requirements. Watch out for older computers, though; computer systems sold prior to 1982 were exempt from any limits, and some are very noisy.

Also be careful with peripherals. Connecting a Class A peripheral (modem, printer, monitor) can increase the emissions from the entire system to the Class A limits.

Finally, when working inside your computer, be sure to "button it up" when you're done. Leaving out cabinet screws or metal covers

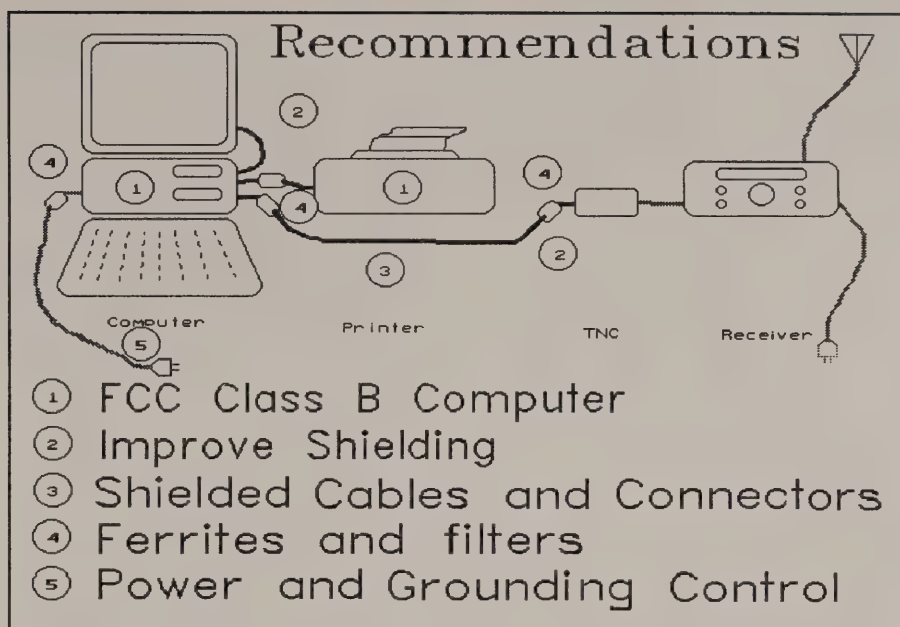


Figure 4

on the I/O, for example, can seriously degrade your computer's built-in RFI protection.

Improve the Cabinet Shielding

This is not as difficult as it first sounds. Most computers today use cabinets that are metal or metal-paint on plastic. These materials can provide very good shielding, but they leak at seams, slots, and non-filtered conductors. These leaks can often be sealed with additional screws, gaskets, or copper or aluminum tape.

A quick way to find leaks is with

a "sniffer probe." Figure 3 shows how to make such a probe, which is nothing more than a small high frequency magnetic field probe. Simply connect the probe to your receiver (tuned to a computer "birdie"), and move it over cabinet seams, cables, and connectors. Any that are hot are leaking energy, and should be sealed. Pay particular attention to the peripheral connectors. If any energy is leaking there, it can easily couple to the cables which can then act as very efficient antennas.

Cables and connectors

Shielded cables with high quality metal connectors on both ends are recommended for computers in the ham shack. A few extra dollars spent here can prevent radiation, both from the inner wiring due to leakage and from the shield itself.

Proper grounding of the cable shield and connector is very important. Even the best shield will leak if a proper ground is not provided. This means a full circumferential bond from shield to cable-connector, and from the cable connector to the cabinet connector. The key is to provide full metal-to-metal

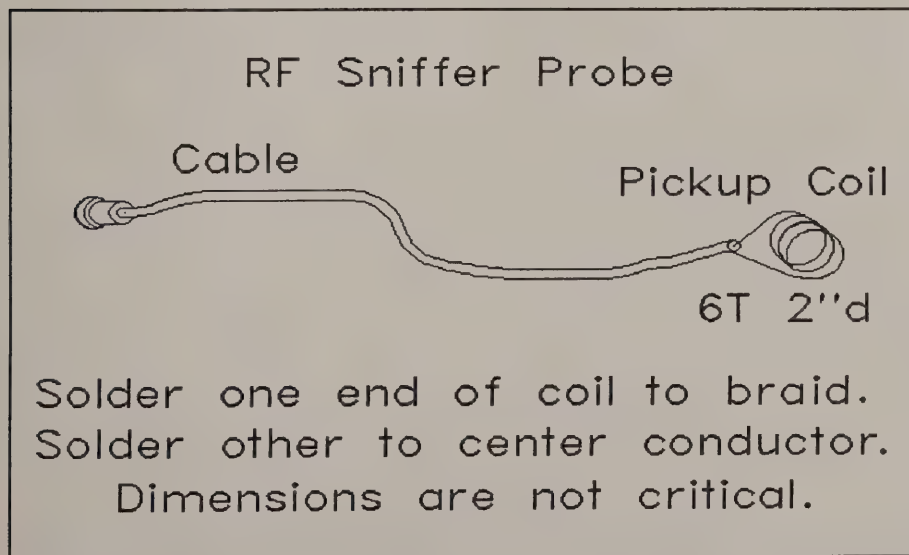


Figure 3

contact on both ends of the cable. (Copper or aluminum tape can be very helpful here.) Incidentally, pigtailed for grounding are not good enough -- if your cables use pig-tails, change or replace them!

Ferrites and Filters

Ferrites can help reduce cable radiation. Clamp-on ferrite cores are available, similar to those used in ferrite baluns. These lossy devices actually absorb the unwanted noise currents flowing on cables. Try the ferrites on both ends -- one end may work better than the other due to the source location or standing waves on the cable.

Bypass capacitors can also help reduce cable radiation. If not bypassed, even a single wire run into a shielded computer enclosure can severely degrade the shielding (it acts like a probe in a microwave cavity). Thus, any unshielded lines should be bypassed to the

case with 0.001 or 0.01 uf capacitors. For RS-232 lines, add-on bypass filters are available at moderate prices from electronic suppliers.

In extreme cases, fiber optics may be needed. Several companies now provide fiber links that replace existing RS-232 lines. They are a bit expensive, but they are very effective. Since they are non-conductive, they would work quite well on a computer-to-radio interface, if both conducted and radiated paths were of concern.

Finally, don't overlook cable routing. Moving that printer cable away from the coaxial cable might do wonders for the computer-RFI coupling directly into the coax. It might help reduce some mysterious failures to the computer when transmitting, too.

Power and Grounding

Most computers today have some filtering on input power. Nevertheless, additional filtering, bypassing, or ferrites on the power lines can help. Remember, the power lines can act as both antennas (radiated path) and energy carriers (conducted path.) Don't overlook separate AC power circuits for the computer and radio equipment either.

While most hams are careful about grounding their radio equipment, they are not so careful about grounding the computer. Following "radio guidelines" and bonding the peripherals together can often help reduce computer

RFI. Above all, make sure all your equipment is safe -- a 60 Hz safety ground on every piece of equipment is a **must!**

To summarize -- Computers are rich sources of radio frequency emissions. With increasing clock speeds and logic rise/fall times, these energy levels continue to increase.

At the same time, receivers are very sensitive victims to such interference. The FCC regulations for computers are a start, but in many cases they are not enough. Remember, they were designed to protect television receivers, not sensitive communications receivers.

In order to prevent and fix these problems in your ham shack, good rf design techniques are needed, and both radiated and conducted coupling paths must be considered. Particular attention should be given to the computer shielding, cables and connectors, and power and grounding.

The bottom line is to treat your computer like a radio transmitter, because, in fact, it is.

Daryl Gerke, KØFBF, is a registered professional engineer and a partner in Kimmel Gerke Associates, Ltd., an electrical engineering firm that specializes in solving interference problems. A dedicated ragchewer and DX chaser, he was first licensed in 1960, and holds an Advanced Class license and a First Class Commercial License. Daryl can be reached in St. Paul, Minnesota, at (612) 646-7715.

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CQ Twenty. . .

by C. W. Curmudgeon

It was spring. One of those rare days when everything seems so perfect you are afraid you will wake up and find you have been dreaming. Cool, crisp, and sunny, just made for putting the finishing touches on your new antenna.

Dave was proud of his new station. He had put in a lot of hours designing it during the war. Now, two years after the Japanese surrender, he was ready to settle down to some good ragchewing and a little serious DXing.

With no small amount of pride, he stood back and admired his antenna. The two-element, 20 meter beam was only a bunch of odd parts and rusting junk a few months ago. Now the thirty-foot windmill tower, found rusting on a farm, stood tall and proud, once again serving a useful purpose. The farmer was glad to have it removed. Dave had completely disassembled the tower, then, after sanding for days, he had primed and painted the metal with aluminum paint and used new stainless steel bolts to reassemble it. Nothing but the best would go into this antenna.

Two booms, of 2 x 2 redwood spaced sixteen inches apart and reinforced with marine plywood, were then given three coats of outside varnish. The two elements, made of electrical conduit, were painted with aluminum paint before being attached to the booms. The overall appearance

was very pleasing. Best of all, it worked as good as it looked.

The rotor had been the most work. Good antenna rotors cost a lot in 1947, most beams being turned by converted prop pitch motors, or by the "arm-strong" method. Dave had mounted a rear end from a junked automobile at the base of his tower. Tower legs and the differential housing were attached to a concrete base with bolts set into the concrete. Dave spared no effort in the construction of his antenna. The drive shaft was coupled through galvanized pipe to the top of the tower. The axle extended through the wall of the shack. A Ford steering wheel with a "spinner knob" was attached to the axle. A gear system off the axle was attached to a pointer to indicate direction.

Dave was thankful for the availability of coax. It sure saved him a lot of time. Devising slip rings for the beam would have been a bigger job than installing the rotor.

Going into the shack, he sat down in the old office chair. Leaning back, he felt at peace with the world. All was good. He could hear Ellie out in the kitchen, preparing supper. Soon the children would be in from play and they would all enjoy a delicious meal. Afterward, he and Ellie would sit on the divan listening to the radio while the children lounged on the floor or worked on tomorrow's school assignments.

Ellie was just as pretty as she

was when they were married in 1934. He enjoyed these evenings at home. After eight, he would retire to the shack and get in three or four hours of hamming. Ellie always understood his need of this time with his hobby. After all, she had helped him save the few dollars each month to buy parts for his post-war dream rig. With all modesty, he must admit he had one of the finest shacks in town. For receiving he had his faithful Hallicrafters SX-28 and a surplus BC 348.

On the desk, with the receivers, was the Astatic Mike, and both a Vibroplex and Mac bug. He knew that two bugs were a luxury, but they were each beautiful in their own way, just as each were very different to use. He could not say which he preferred; both were a joy to operate.

His pride and joy was the "rig" sitting by the desk. He had planned this new transmitter, down to the last detail, while he served as a radio-op in the Air Force during the war. Starting construction in the winter of 1945-46 he had spent months building it. It had to be as pretty inside as out. He used a 6L6 oscillator, an 807 buffer-doubler, and a pair of 813's in the final. The power supply for the final used 866 rectifiers. At the base of the six-foot rack he had cut a window in the panel and covered it with screen wire so he could watch the flashing of the 866's as the transmitter was keyed. A window, covered with glass, was

in front of the 813's so he could watch the warm glow of the tubes. Dave loved the sights and sounds of radio.

Noticing a move in the past few months to electron-coupled oscillators, or VFO's as we now know them, he had saved his money and purchased a Meissner Signal Shifter. Now the rig was complete. Yes, after fifteen years of hamming, he had the station of his dreams.

As he pulled up the chair to the operating desk, he could feel the warm sunshine on his back as it came through the west window. It felt good this cool day. Turning on the SX-28, he figured he had enough time for a QSO or two before supper. He flipped the

filament switch in front of him and the remote relay in the rack clicked as the 813's came to life. After tuning the band and not hearing any DX he decided to try a CQ. CQ CQ CQ de W. . .

"Mr. Gibson, Mr. Gibson, are you awake? It is time I wheeled you back to your room. You have had enough sunshine for today. We must get you ready for supper. Tonight we are having soup -- and ICE CREAM for dessert," said the nurse, as she tucked the blanket around his legs and pushed the wheelchair from the porch.

"We must get you shaved and a clean shirt on. Tonight is Wednesday. This is the night your grandson is bringing your new great-granddaughter by for a visit." The

nurse wondered if he had heard. She made a mental note to ask the doctor about the peculiar twitching of Mr. Gibson's right hand. It seemed his fingers were in constant motion.

Shutting out the sights, sounds, and odors of the Happy Manor Nursing Home, with a mind trained by years of DXing thru heavy QRM, Dave returned to a better time. Reaching for the Vibroplex, he resumed his CQ, CQ, CQ. . .

C. W. Curmudgeon is the pen name of an Old Coot who lives beyond the reaches of a Rural Route. He has requested that we hold his mail until he comes down out of the hills.

Sparks from the Past

by W. J. Byron, W7DHD

Years ago, say before 1923, it was possible to turn the receiver on (if you were well-heeled enough to have one -- otherwise you used a crystal and a cat's whisker) and hear all sorts of raucous signals, some with musical notes, some with a 60 Hertz buzz, and some with a shattering crackle. They all had one thing in common -- they were *broad* and nearly inseparable! What were they? How did they work?

Many techniques developed then are still in use today -- more than most people realize -- and we owe a great deal to our radio forefathers.

Almost everyone has heard of "spark transmitters," but since they disappeared by edict nearly 70 years ago, few people are alive who have heard them. Even fewer understand how they worked.

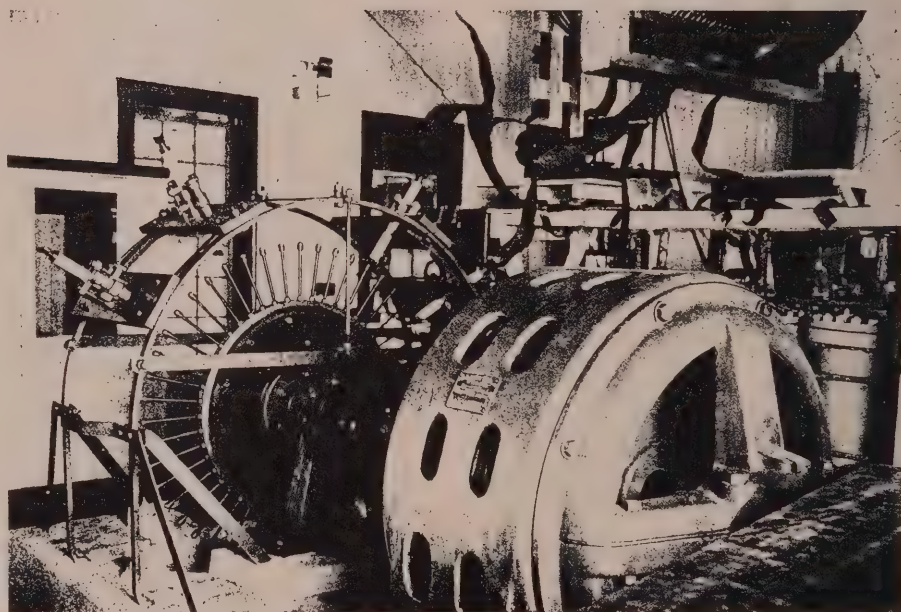


Figure 1: Rotary spark-gap transmitter.

Nevertheless, they were the only means by which radio signals could be transmitted, even over short distances.

It didn't take long for the engineers of the day to develop the

technology to a remarkable level, enabling worldwide communications via "spark" technology. Pre-eminent in the early twentieth century was Dr. Jonathan Zenneck, along with Marconi, of

course, Tesla, Popov, Hertz, Alexander, and Goldschmidt.

Probably the very first to radiate and detect electromagnetic waves was Heinrich Hertz. It is interesting that his devices radiated in the high-frequency part of the spectrum and consisted of a number of single-turn loops, closed on themselves to terminate in a single ball-gap. He was the first to describe the electromagnetic behavior of loops and even of reflection. The excitation was probably the very first use of the spark, though it was only a single spark event, i.e., not repetitive. By exciting one loop, a second identical loop, if held in the "right position," would exhibit a spark across its own gap. Although his experiments were of enormous importance, they remained as laboratory curiosities. It was left to others to develop radio as it eventually evolved.

Subsequent experiments, such as those carried out by Marconi, were done at extremely long wavelengths -- kilometers -- representing frequencies on the order of 10 to 50 kHz, where single-turn loops were impossible. Either by design or by normal development, including trial-and-error methods, the typical antenna types were developed. They were universally the physically short (less than 90 degrees) combination top-and-base-loaded verticals which are still called "Marconis" for obvious reasons.

Damped Waves

All spark transmitters are of the "damped wave" type, meaning that the energy starts abruptly at some high level determined by the total energy in the system and then decreases *exponentially*. Depending on the value of the log decrement, some circuits would oscillate for quite some time, while others would "damp out" (it is damp, not dampen) in a very short time, say

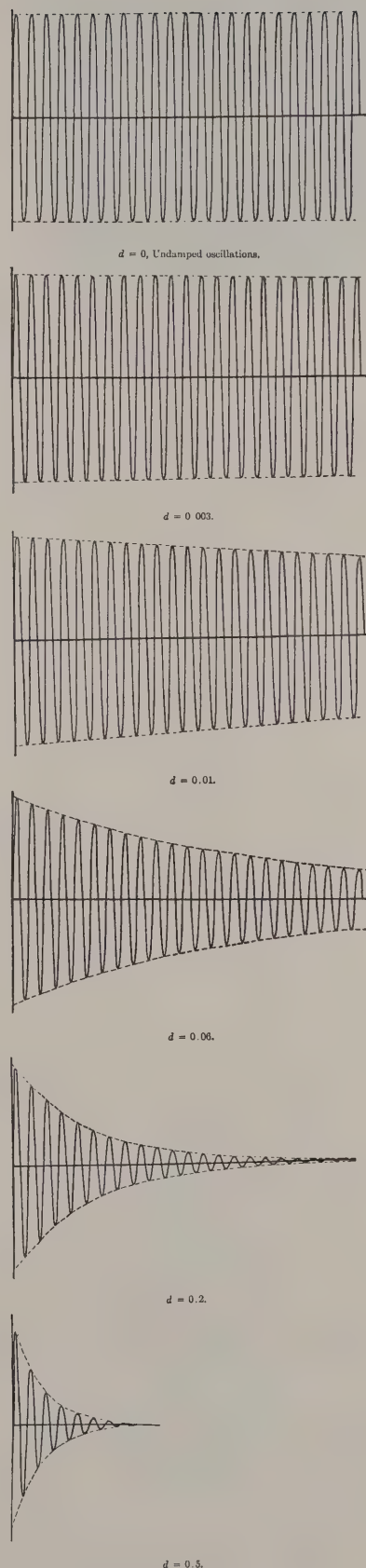


Figure 2: Damped waveforms, characteristic of spark transmissions

within eight or ten cycles. The log decrement is the decrease in amplitude from one cycle to the next expressed as a constant fraction of the preceding cycle amplitude. The electrical system would ring as the result of a sharp excitation pulse, much as a bell rings when struck with a mallet.

Examples of damped waves appear in Figure 2. It begins with the representation of a pure continuous wave (cw) with zero damping, not possible with spark transmitters. The others in the series are for log decrements of 0.003, 0.01, 0.06, 0.2, and 0.5.

For those who think the cathode ray oscilloscope is a new invention, Figure 3 is presented as evidence that it is not. It is a photograph of the face of a Braun tube, which in turn is displaying a damped wave. The Braun tube differed very little in principle from modern oscilloscope tubes, except that it had a cold cathode (as did contemporary x-ray tubes) and was not completely evacuated. By examining the trace, you can estimate the log decrement of the displayed wave form. It is hard to believe that this oscillogram was recorded in 1908.

The spectral width of a transmitted wave is related to its log decrement. One can rationalize that pure cw would have a very narrow width, virtually zero, while a wave with repetitive pulses of a high decrement would be very broad. Imagine the Fourier analysis of a series of waves with a log decrement of 0.5. In 1918 the U.S. Department of Commerce, which governed radio transmitters of the era, promulgated a restriction of the log decrement to 0.2 maximum.

The Transmitters

To illustrate the principle, consider a series resonant circuit consisting of a coil, a capacitor, and a

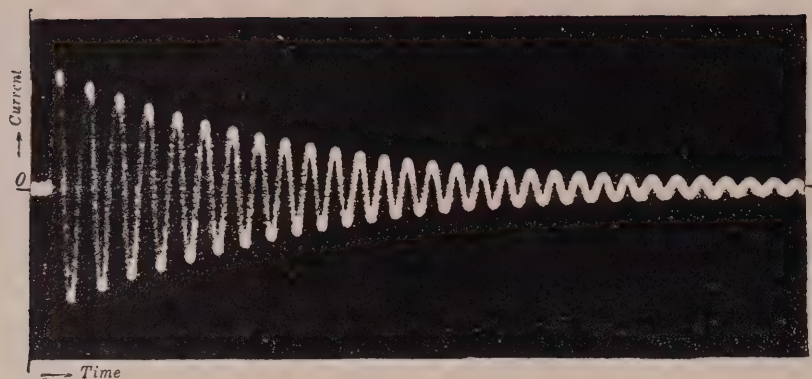


Figure 3: Photograph of oscillogram of a spark transmission waveform.

resistor interrupted by a ball-gap (Figure 4). If a dc potential from a high-resistance source is introduced across the gap, the capacitor will charge to that potential. When the breakdown voltage of the gap is reached, a spark will jump across the gap. When this occurs, the entire circuit will oscillate as long as the spark exists. The spark consists of ionized air, which has a low intrinsic resistance. The oscillations will continue until the voltage developed by the circuit decays via the log decrement to a value below the breakdown voltage of the gap. The "high-resistance source" will not have had time to recharge the capacitor.

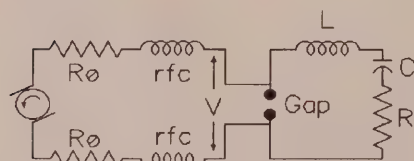


Figure 4: Equivalent circuit.

This last statement is crucial to successful operation -- if either the source resistance is too low or the ball-gap spacing is small enough to allow the gap to "arc" solely under the influence of the source voltage, the system will not oscillate. Variants of this problem plagued all such installations. The remedies consisted of rotary spark gaps of many varieties and eventually of a class called "quenched gaps." It wasn't until the quenched gap was

devised that reliable transmitter operation was finally achieved, especially for small transmitters of the amateur types. Quenching means any method which would prevent sustaining the arc beyond the time that the circuit is oscillating. Figure 1 shows the rotary spark gap of a very high-power spark transmitter. This is one method of "quenching."

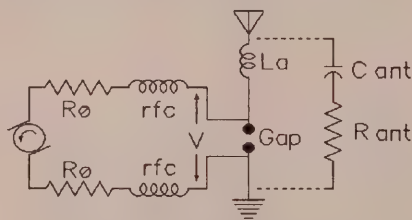


Figure 5: Simple transmitter.

A simplistic representation of the Marconi vertical would be a series resonant circuit consisting of a coil (the self-inductance of the vertical), a capacitor (its capacitance to ground), and a resistance (representing all dissipative elements in the circuit, including the all-important one, radiation resistance). All these elements are shown in Figure 4.

All the elements are shown rearranged in Figure 5. The simplest possible spark transmitter -- the essence of the Marconi method which first spanned the Atlantic is shown in Figure 6. Marconi used 6,000 two-volt storage cells in series for his larger transmitters, which by that time had eliminated the induction coil.

Transmitted Power

Forgetting about extraneous losses for the moment, two factors in the Marconi method determine the maximum power developed -- the capacitance of the antenna itself, and the peak voltage to which that capacitor is charged. Another factor is the repetitive rate of the charging, which raises the average power, but for this illustration we will deal in PEP, a

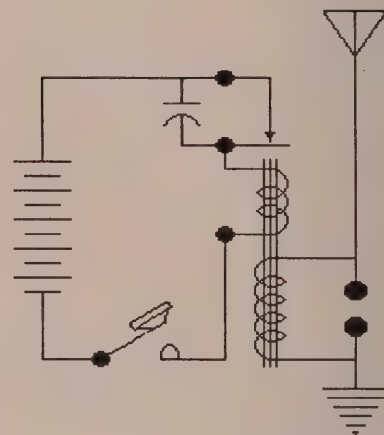


Figure 6: An early spark transmitter -- the basic Marconi.

now-familiar term that wasn't used then. The simple Marconi transmitter had its limitations. It does reveal, however, why the transmitting antenna of the Atlantic experiment was shaped the way it was -- to increase its capacitance. Later antennas all possessed huge flat-tops, L's, or umbrellas, initially for the same reason. Given a fixed capacitance, the only way to raise power was to increase voltage. That had -- and still has -- very serious consequences.

The Braun Transmitter

In 1898 F. Braun patented the Braun System which solved two things: it forced the primary circuit to retain many times the charge that the typical antenna could, hence raising the power capability dramatically, and it lowered the "decrement," thus narrowing the

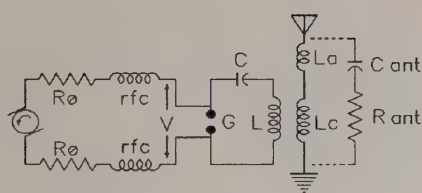


Figure 7: Braun Transmitter.

signal width. The circuit appears in Figure 7.

The energy in the system is:

$$E = \frac{1}{2}CV^2$$

where:

E is energy in joules

C is capacitance in farads

V is voltage in volts

The capacitance, C, can be increased many times over the raw capacitance of the antenna. The total energy can be raised by increasing both the capacitance and the voltage. The consequences of the high voltage exist only in the shack. This principle held sway for more than two decades. It is the one important breakthrough, besides the quenched gap, that enabled successful operation of truly high-power spark transmitters.

And the high power was certainly necessary, first to overcome the distances and QRN, and second because for many years all receivers were of the passive type -- there was no signal amplification, either before or after detection. The *transmitter* had to furnish the power to energize earphones several hundred or thousand miles away. And ample power they had! With the Braun method, transmitter power was raised to hundreds of kilowatts, not all of it radiated because the antennas were notoriously inefficient. For VLF operation, they still are. Transmitter efficiencies, however, were as high as or higher than today's Class-C vacuum-tube transmitters -- better than 85 per cent.

The Braun transmitter was difficult to tune. It exhibited the "dou-

ble-hump" resonance characteristic of all magnetically coupled double-tuned circuits. In modern i-f cans, this is used to advantage; in spark transmitters it was a nuisance.

The Wien Transmitter

M. Wien, a contemporary of Braun's, removed the double-hump characteristic by using one inductor, which replaced the self-inductance of the intermediate

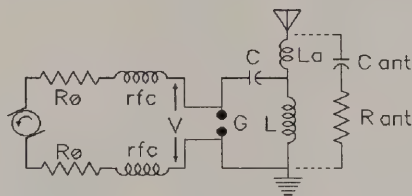


Figure 8: Wein Transmitter

circuit, the coupling coil inductance of the antenna circuit, and their mutual inductance. Its main drawback was that it couldn't divorce the basic decrement of the antenna itself from that of the storage circuit. The large capacitances, hence the large energy storage, were still there, thus enabling high power levels as in the Braun transmitter.

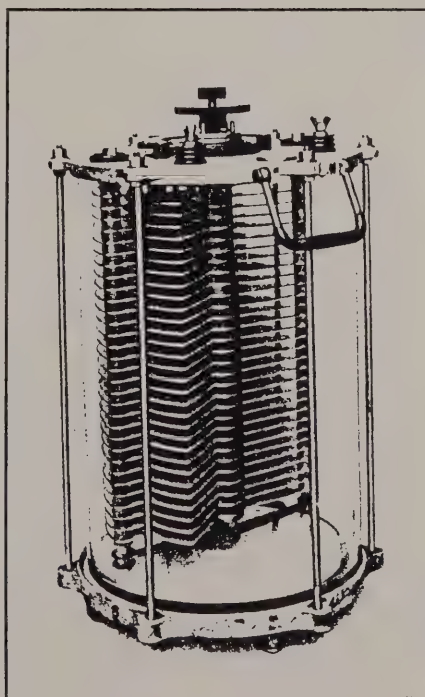


Figure 9: Variable Capacitor.

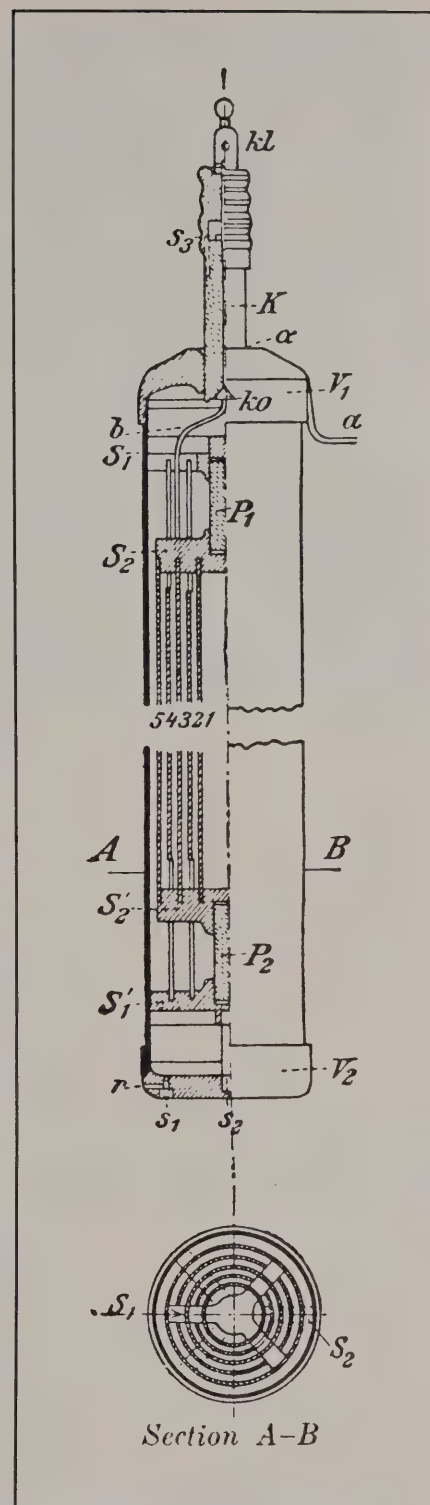


Figure 10: Cylindrical capacitor.

Capacitor Design

Variable capacitors were built exactly as they are today. Figure 9 shows the construction of a variable of that era. It could be modern and, for most purposes, we could use it today. Bakelite, much in use then, is a good insulator

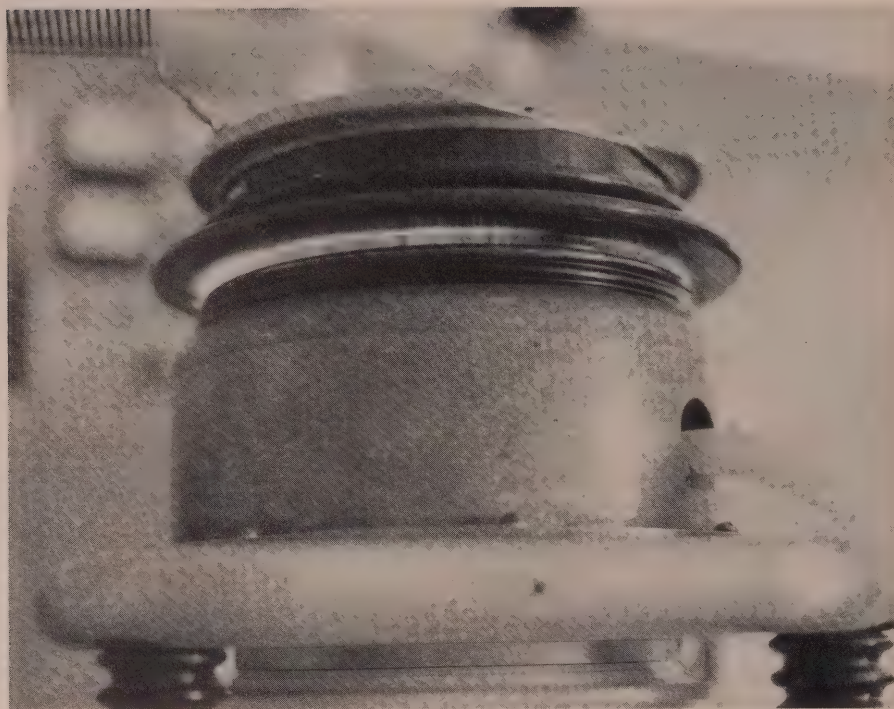


Figure 11: Brush discharge on insulator.

which would suffice for all but VHF use.

High-energy capacitors were a different story. For moderate voltages, oil-filled fixed-plate capacitors were devised; there were even some *variables* built this way. But for the very high voltages, capacitors were constructed with a sealed pressure-chamber around them. Internal construction was of concentric cylinders, much like that of a fully meshed Jennings Vacuum Variable.

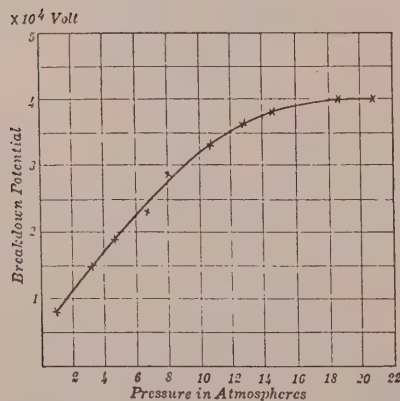


Figure 12: Voltage-pressure relationship.

The chamber was evacuated and back-filled with carbon dioxide under pressure, the pressure often

reaching 20 atmospheres (300 psi). By this means, voltages as high as 40,000 could be applied across spacings of about three millimeters (see Figure 12). Figure 10 describes the typical configuration. Some of these pressure-vessel capacitors are visible to the right of the rotary spark-gap motor in Figure 1. Notice the heavy construction and the flanges at the top.

A Modern Application

Just a few years ago there was a problem with "flashover" in a very modern piece of equipment at the Princeton Plasma Physics Laboratory. A special variable capacitor was required to withstand 100,000 volts at 25 MHz but exhibited the symptoms of flashover during operation. The dielectric in the capacitor was one of the liquid Freons (TM). Constructed so that it resembled a vacuum variable, it was really of a micrometer-screw type.

The task of trouble-shooting the failure fell to Tony Sivo, W2FJ, who at the time was in PPPL's

power electronics department. The failure was thought to be inside the dielectric, but to test such a capacitor at full voltage outside the equipment is difficult. In a short time, Tony constructed a spark generator from a spare set of tungsten ball-gaps, a 100 kV dc "high-potter," a piece of B&W coil stock, and the capacitor in question. The results were spectacular (see Figure 11). There was a "brush discharge" around the insulator, much like those experienced by spark transmitters of yore. But there is more to the story. *The brush discharge originates from the surface of a ridge on the insulator and terminates on the insulator!* It does not flash from conductor to conductor. There was nothing wrong with the capacitor but there was something wrong with the design of the insulator. So much for those who think the design of insulators is simple. The design allowed the voltage gradient around the ridge to exceed the breakdown potential of the air surrounding it. The breakdown occurred at about 80,000 volts, considerably lower than its design voltage. The frequency turned out to be just above the broadcast band. (Do not try this outside a shielded room or, like Marconi, you might be heard on the other side of the Atlantic!)

Bill Byron, W7DHD, says he took most of the techniques and equipment descriptions for this article from the book, Wireless Telegraphy by Zenneck. Bill is indebted to Frank Chess, K3BN, who gave him the book, to Tony Sivo, W2FJ, who supplied the spectacular photo of the brush discharge, and to Walter Shulz, K3OQF, who helped and encouraged him. Bill's address is P.O. Box 2789, Sedona, AZ 86336.

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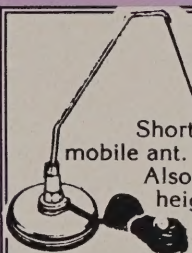
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Electromotive Force

Charge carriers will not move in a conductor unless they are caused to do so. The force required is the electromotive force and the result of the charge motion is the electric current.

The rationalized MKS (Meter Kilogram Second) system of units is the worldwide standard for measurement used in the electronics industry. In the MKS System the unit of energy is the joule and the electromotive force, emf, is measured in joules per coulomb -- the potential energy of each unit of charge, just as in mechanics where the force of gravity is the gravitational potential for each unit of height. One joule per coulomb is one volt. Smaller emf's are more conveniently expressed in millivolts and microvolts, one-thousandth and one-millionth of a volt respectively. Large emf's are measured in kilovolts, thousands of volts. Emf can be positive, zero or negative.

Consider a very high voltage dc source connected between two large spherical metal balls. The whole apparatus sits on a table. The table can arbitrarily be chosen to be zero volts. The positive emf is the voltage with respect to the table on the sphere that induces positive charge carriers to leave its surface. The negative emf is the voltage with respect to the table on the sphere which induces electrons -- negative charge carriers -- to leave its surface. Notice that voltage is always a difference of emf between two points. One may

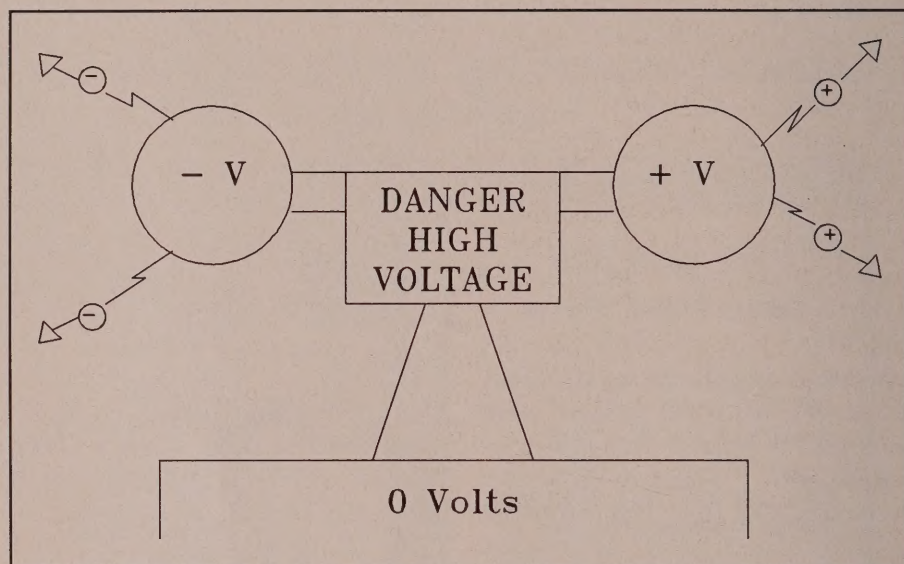


Figure 1 : High voltage dc source.

be an arbitrarily chosen reference (the table).

The ac electrical power in a house has a maximum (peak) emf of about +170 volts and a minimum emf of about -170 volts. The equivalent dc emf, which would produce the same heat in a resistor as the ac produces, is 120 volts dc. We say that the ac is 120 volts rms. The letters rms stand for "root mean squares," shorthand for the method of calculating the equivalent dc voltage of perfect sine wave ac. Typical chemical cells develop about 1.5 volts of dc emf; the exact value depends on the particular chemical reaction involved and how it is affected by the temperature and pressure.

The volt is named for the Eighteenth Century Italian physicist Alessandro Volta. Count Volta

made the first electrochemical cells and collated these into a stack called a battery of cells. When the electromotive force causes an electrical current to flow for a length of time, work is done. Volta had found a way to do electrical work in exchange for chemical work -- the battery. Michael Faraday found a way to do electrical work in exchange for mechanical work -- the generator. And Heinrich Hertz found a way to do electrical work in exchange for radiant energy (energy being equivalent to work) -- the antenna. Many of the common electrical devices -- motors, generators, light bulbs and batteries -- are used to convert one sort of work or energy into another sort of energy or work. Don't get confused about work and energy -- in physics they

are different names for the same thing.

In an electrical circuit there are *sources* of electrical work where emf is increased and *sinks* where mechanical or other work is done and emf is decreased.

In the simplest circuit there is one source, say a battery, and one sink, say a light bulb. The behavior of this circuit can be compared to that of a roller coaster. From the start a roller-coaster car is pulled by a chain drive to the top of the track. The car rolls down the track to a braking block where a quantity of mechanical energy is turned to thermodynamic work (heat flow). At this point the car is again pulled up to the top of the track by the chain drive, etc.

The sharp-eyed reader will notice that most roller coasters go up and down while the one representing the simple circuit always goes down. Roller coasters can go up and down because the car on a roller coaster has inertia. The mechanical system has kinetic as well as potential energy. If we added electrical inertia to the simple circuit (inductance and capacitance) then it would have kinetic energy and the emf would go up and down too, but we would lose all the simplicity.

From the all-downhill roller coaster, whose kinetic energy is a function of height, we can draw

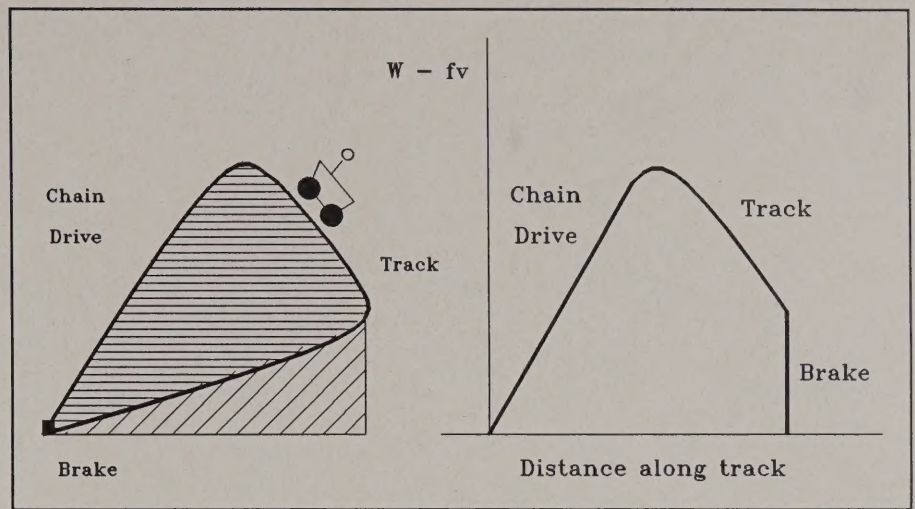


Figure 2 : A roller coaster and its mechanical potential.

several conclusions about the simple circuit:

1.) Where work is done on the circuit, the potential (emf) increases -- the chain drive.

2.) In the circuit wires the potential decreases due to resistance in the wire -- friction at the track and in the bearings.

3.) At the light bulb where external work is done the emf falls dramatically as the circuit energy is converted to another desired form of energy -- the braking block.

4.) The operation is independent of the absolute value of the voltage -- height of the roller coaster above sea level. After all, the roller coaster would work in Denver as well as it would work in Coney Island even though the one

in Denver is a mile higher.

If the electrical current in coulombs per second (amperes) is multiplied by the emf in joules per coulomb (volts), the result is joules per second, which is watts -- the power. Thus:

$$P = IE$$

where:

P is the power in watts.

I is the current in amperes.

E is the electromotive force in volts.

In any part of the simple dc electrical circuit (a component) the power *leaving* the circuit is the product of the emf dropped across the component and the current through the component. This is true within the power source as well, but the product of current and voltage drop is the power *supplied* by the battery.

The methods of measuring and using electromotive force will be covered in future issues of BEAM.

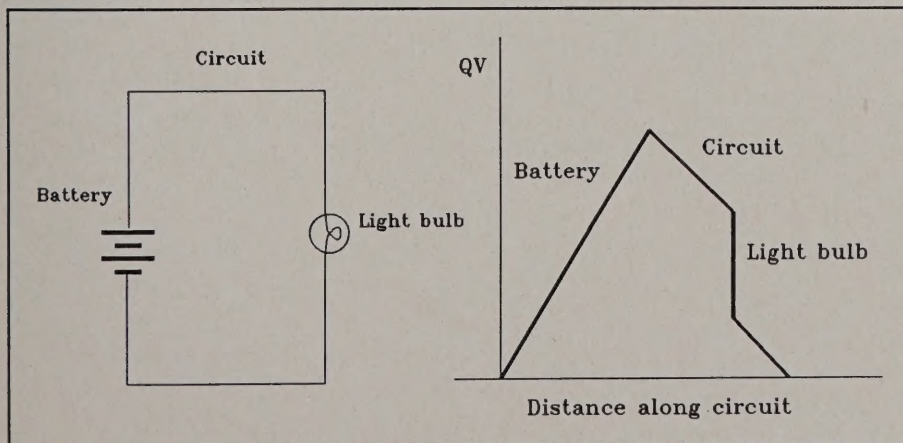


Figure 3 : A simple circuit and its electrical potential.

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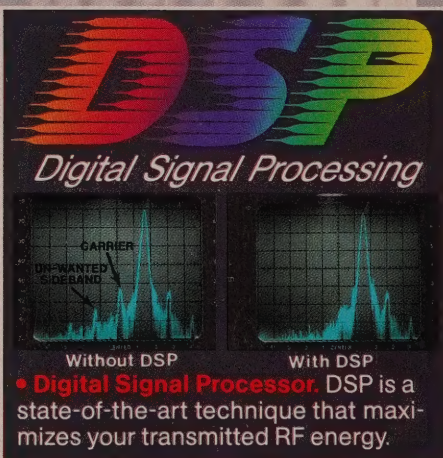
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